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Mars Spark Source Prototype

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Summary

The Mars Spark Source Prototype (MSSP) hardware has been developed as part of a proof of concept system for the detection of trace metals such as lead, cadmium, and arsenic in Martian dusts and soils. A spark discharge produces plasma from a soil sample and detectors measure the optical emission from metals in the plasma that will allow their identification and quantification.

Trace metal measurements are vital for the assessment of the potential toxicity of the Martian environment for human exploration. The current method of X-ray fluorescence can yield concentrations only of major species. Other instruments are incompatible with the volume, weight, and power constraints for a Mars mission. The instrument will be developed primarily for use in the Martian environment, but would be adaptable for terrestrial use in environmental monitoring.

Tests were performed to characterize the prototype's performance in 1 Atmosphere of air, as well as 10 Torr of air, and 10 Torr of carbon dioxide. 10 Torr of carbon dioxide approximates the Martian atmosphere. This paper describes the Mars Spark Source Prototype hardware, the results of the characterization tests, and future plans for hardware development.

Introduction

The NASA Glenn Research Center initiated the development of the MSSP as part of a Director's Discretionary Fund (DDF) project for the Spark Analysis Detection of Trace Metal Species in Martian Dusts and Soils. The objective of this project is to develop and demonstrate a compact, sensitive optical instrument for the detection of trace, hazardous metals in Martian dusts and soils.

The MSSP was developed from inexpensive, readily available, commercial components to minimize cost and development time. Miniaturization and optimization can be implemented to greatly reduce the size of the hardware and improve its efficiency for space applications.

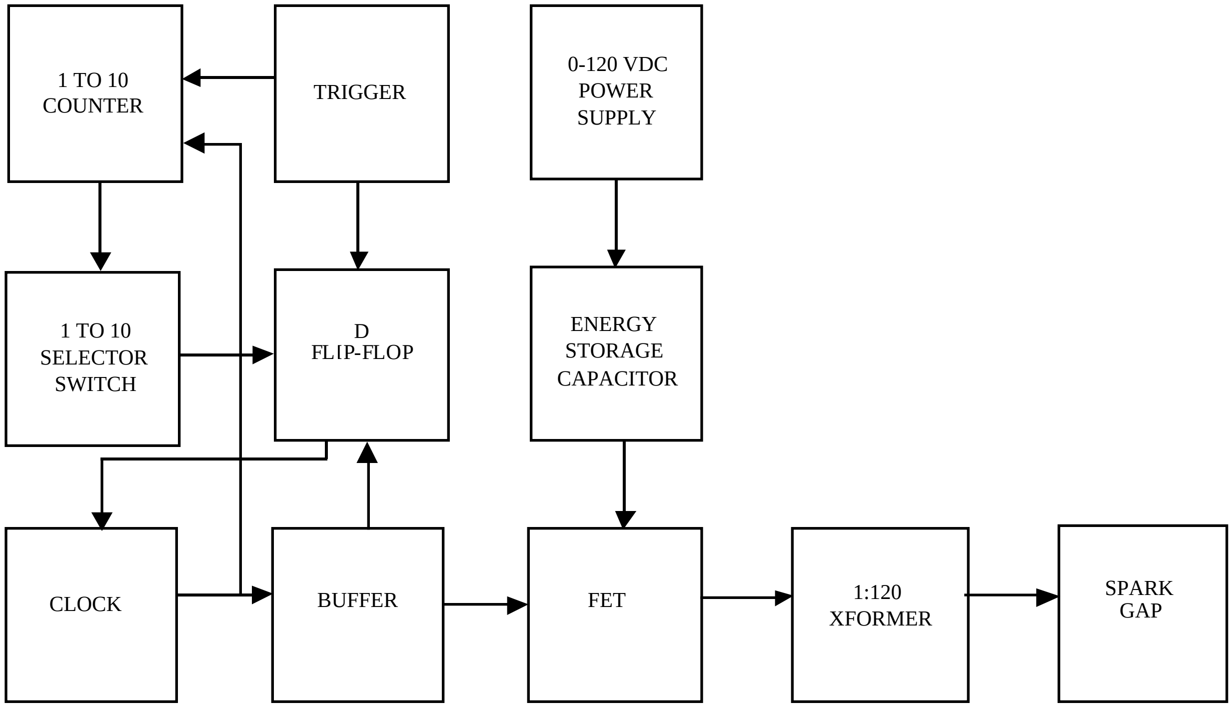
Hardware Description

A block diagram of the Mars Spark Source Prototype is shown in figure 1 and the circuit is described in detail in appendix A.

A clock is used to provide a pulse train. The pulsewidth is adjusted at the clock. The output of the clock is taken to a counter and to a flip-flop. Triggering the circuit resets the counter and the flip-flop. A selector switch from the output of the counter selects the desired number of pulses from one to ten. After the preset number of pulses has been attained, the flip-flop inhibits the clock until the circuit is triggered again.

The output pulses go to a buffer that drives an FET. The FET provides power from a 0 to 120 V dc power supply and an energy storage capacitor to the primary winding of a pulse transformer. The secondary winding of the pulse transformer is connected to a spark gap.

Figure 1 - Mars Spark Source Prototype Block Diagram



The configuration of the MSSP hardware is shown in figure 2. The MSSP hardware consists of a Control Box, a Power Box, a Power Supply, and the interconnection cables. The Control Box provides all of the user's controls including a power switch, a pulsewidth selector switch, a pulsewidth dial, a pulse quantity switch, and a spark initiation switch. The Power Box contains all of the power electronics. It is connected to the Control Box through a single control cable. The Power Box also has a power switch that connects a bleed resistor to quickly safe the system when the switch is turned off regardless of the state of the other system components. The Power Supply provides power to the Power Box. The spark voltage amplitude is 120 times the dc voltage derived from the Power Supply. The spark voltage is connected to the spark gap via two high voltage cables.

The hardware specifications are listed in table I. The schematic diagram, interconnection diagram, and parts lists are included in appendix A for reference.

Figure 2 - Mars Spark Source Prototype Configuration

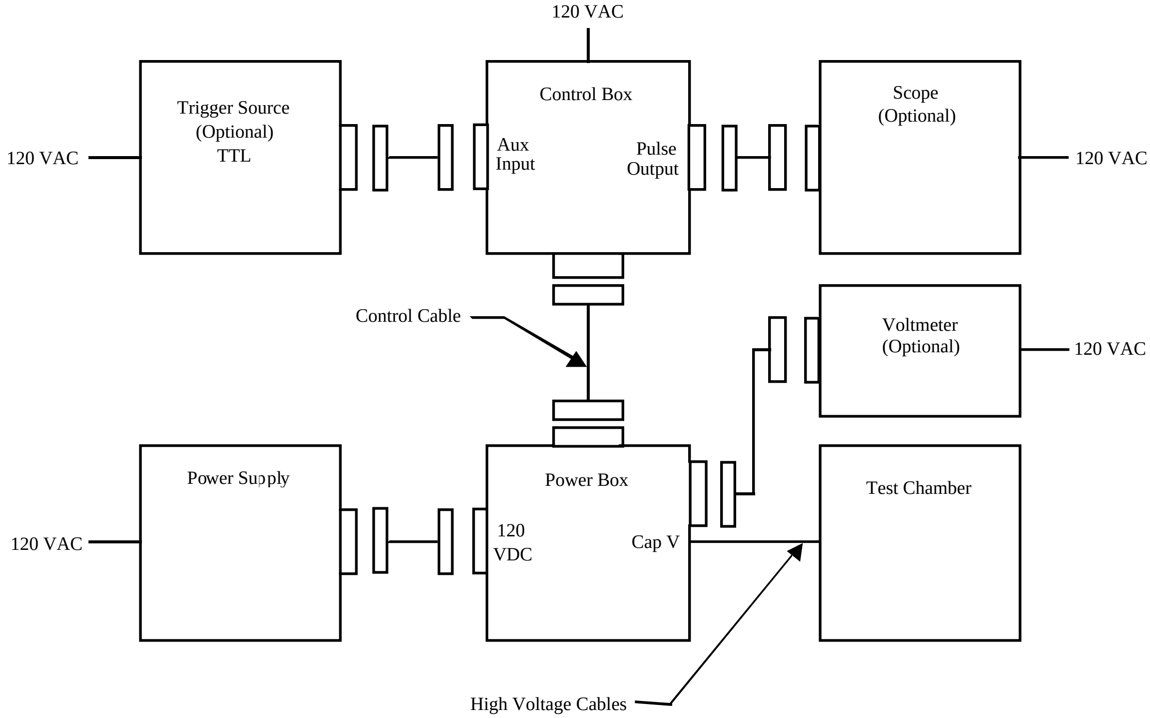


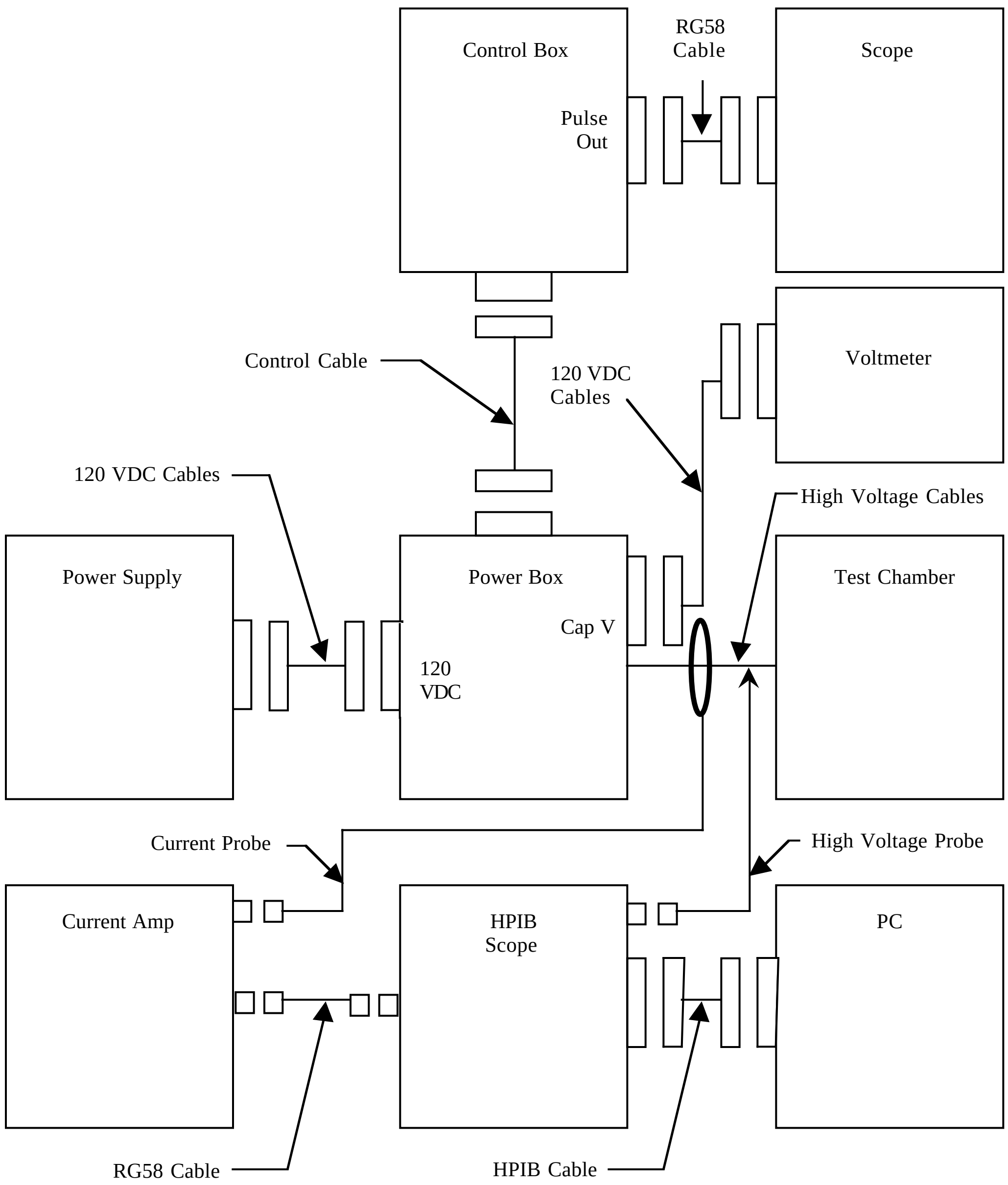
TABLE I.—HARDWARE SPECIFICATIONS

CONTROL BOX	
Power Input	120 VAC
Auxiliary Input	TTL Compatible
Pulse Output	15 VDC
Pulsewidth	4 to 11 microseconds
Number of Pulses	1 to 10
POWER BOX	
Power Input	0 to 120 VDC
Capacitor Output	0 to 120 VDC
High Voltage Output	0 to 14.4 kV

Test Description

The MSSP test configuration is as shown in figure 3. A list of the test equipment and a description of the test configuration is included in appendix B.

Figure 3 – Mars Spark Source Prototype Test Configuration



The Mars Spark Source Prototype was tested with a 0.5 mm tungsten electrode to a stainless steel plate. The spark gap was tested at 2, 5, and 10 mm. Atmospheres of 1 Atmosphere of air, 10 Torr of air, and 10 Torr of Carbon Dioxide were used. Pulsewidths of 4, 10, 50, and 100 microseconds were used in pulse bursts of 1, 2, 5, and 10 pulses. Pulse voltages of 1, 2, 5, 10, 12, and 14.4 kV were applied where possible within the safe operating area of the hardware. Each point was tested three times to determine variation. The energy of each test point was derived from the software that was developed for this application.

The test matrix for the Mars Spark Source Prototype is shown in table II.

TABLE II.— MARS SPARK SOURCE PROTOTYPE TEST MATRIX

Gap	2 mm, 5 mm, 10 mm
Atmosphere	1 Atmosphere Air, 10 Torr Air, 10 Torr Carbon Dioxide
Pulsewidth	4 µs, 10 µs, 50 µs, 100 µs
Number of Pulses	1, 2, 5, 10
Pulse Voltage	1 kV, 2 kV, 5 kV, 10 kV, 12 kV, 14.4 kV (as possible within the safe operating area of the hardware)

The mean energy for each of these test points has been tabulated in appendix C. A plot of the mean energy for each of the test modes as a function of voltage has also been included in appendix C.

A summary of the test results is shown in table III.

TABLE III.—SUMMARY OF TEST RESULTS FOR THE MARS SPARK SOURCE PROTOTYPE

Atmosphere	Pulses	Energy (millijoules)		
		Gap (mm)		
		2	5	10
1 Atmosphere Air	4 µs, 10 pulses, 14.4 kV	2.8	3.6	-
	10 µs, 10 pulses, 14.4 kV	3.6	17.6	-
	50 µs, 10 pulses, 10 kV	32.4	31.0	-
	100 µs, 10 pulses, 5 kV	45.8	-	-
10 Torr Air	4 µs, 10 pulses, 14.4 kV	8.1	10.2	11.0
	10 µs, 10 pulses, 14.4 kV	19.0	23.6	28.5
	50 µs, 10 pulses, 10 kV	35.3	40.8	28.2
	100 µs, 10 pulses, 5 kV	38.8	42.2	44.6
10 Torr Carbon Dioxide	4 µs, 10 pulses, 14.4 kV	10.0	12.0	11.2
	10 µs, 10 pulses, 14.4 kV	27.4	25.0	26.2
	50 µs, 10 pulses, 10 kV	46.3	36.8	38.6
	100 µs, 10 pulses, 5 kV	47.0	44.3	44.7

Concluding Remarks

The Mars Spark Source Prototype tests have shown that the concept of providing multiple sparks in a Martian atmosphere is very effective. The MSSP was assembled with readily available commercial off the shelf components. Significant improvements in performance, weight, and size of the equipment are easily attainable if a space ready configuration is desired.

The power requirement of the prototype has proven to be very small, so a system powered by Mars Lander solar cells appears to be completely feasible. Optimization of the hardware design and operating procedure could reduce system power requirements further.

References

1. J.R. West, T.J. Ticich, R.L. Vander Wal, and P.A. Householder, "Trace Metal Detection by Laser-Induced Breakdown Spectroscopy," Poster presentation at the American Chemical Society National Meeting, Anaheim, CA, March 21-26, 1999.

Appendix A

Mars Spark Source Prototype Hardware Description

The schematic diagram of the MSSP circuit is shown in figure A-1. The parts list is shown in table A-1. The interconnection diagram is shown in figure A-2.

Power for the MSSP circuit is derived from the 120 vac line via fuse FU1 and switch S1. The 120 vac power is provided to power supply PS1 that provides 15 vdc to the circuit. LED1 is illuminated when the circuit is on.

Timer U2 is configured as a resetable astable multivibrator that acts as a clock for the circuit. There are two ranges for the clock which are selected from switch S5. A dial on the front panel sets the frequency of the clock via potentiometer R9, and the range is limited by trim potentiometer R8. The clock is inhibited by flip-flop U4 until it is reset by pushbutton switch S2 or relay K1. K1 is activated through the AUX INPUT via opto-coupler U6. The AUX INPUT circuit was configured to be TTL compatible.

Counter U1 is preset to count from one to ten pulses by selector switch S3. U1 is reset when the clock is reset. The clock is reinhibited by the flip-flop when the preset number of pulses is attained.

The pulses from the clock are taken to the PULSE OUTPUT via buffer U3 for observation if so desired. The pulses are also taken to the gate of FET Q1 via buffer U5. Q1 provides a pulse of power to the primary of pulse transformer T1. Diode D1 is a flyback diode to protect Q1. Resistor R14 limits current in the primary winding of T1. Power for T1 is derived from capacitor C9 that is charged by a 0 to 120 Vdc power supply. The capacitor voltage can be monitored directly at the CAP V outputs. Resistor R12 limits the power supply current. Switch S4 is used to shut down the high voltage section safely. When S4 is OFF, it opens the circuit from the power supply and inserts bleed resistor R13 across capacitor C9 to discharge it in less than one second. LED2 indicates if S4 is ON.

T1 is a 1:120 pulse transformer. Therefore, the voltage at the secondary winding of T1 is adjustable up to 14.4 kV. The secondary winding of T1 is connected to the spark gap by high voltage cables via high voltage insulators I1 and I2.

Figure A-1 Schematic Diagram

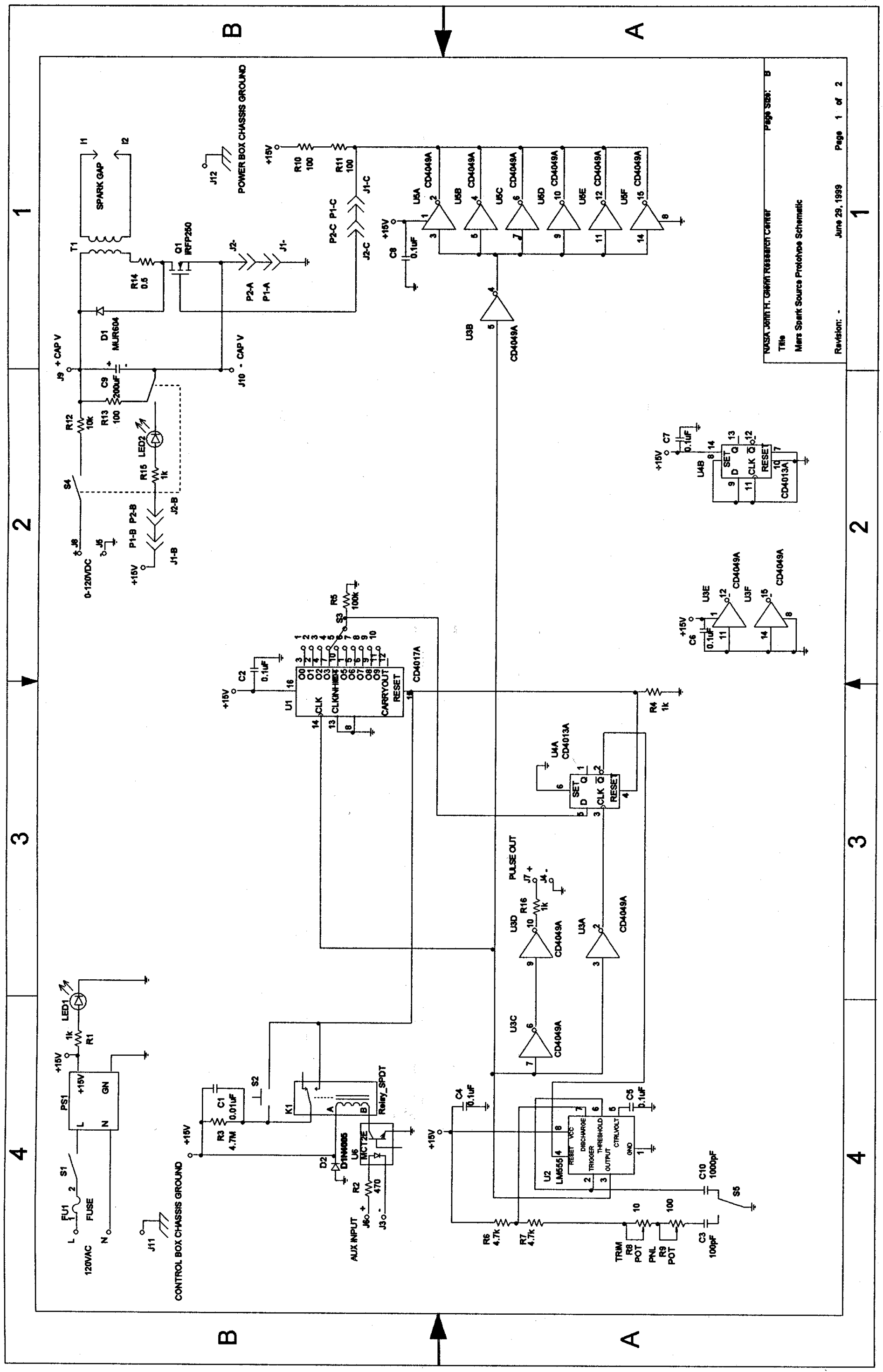
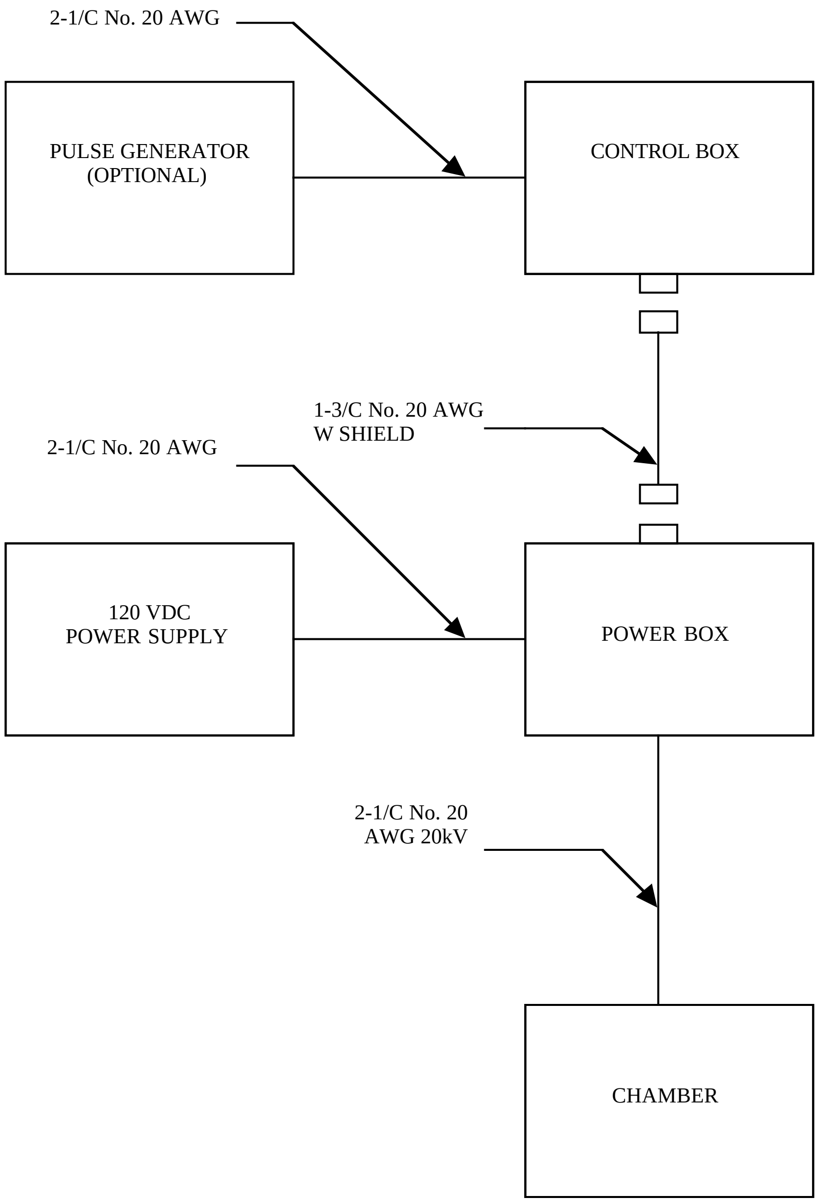


Table A-1 Parts List

No.	Description	Qty.
U1	Microcircuit, 4017, NSN 5962-01-226-8855	1
U2	Microcircuit, 555, NSN 5962-069-3045	1
U3, 5	Microcircuit, 4049, NSN 5962-01-309-1046	2
U4	Microcircuit, 4013, NSN 5962-01-014-8081	1
U6	Microcircuit, MCT2E, NSN 5980-01-062-2726	1
PS1	Power Supply, 15 V, NSN 6130-01-022-0813	1
S1, 4, 5	Switch, Toggle, NSN 5930-00-880-9878	3
S2	Switch, Pushbutton, NSN 5930-00-677-2334	1
S3	Switch, Rotary, NSN 5930-00-817-3738	1
	Detent, NSN 5930-00-548-6781, Knob, NSN 5355-00-701-2862	1
LED1, 2	Light, Indicator, NSN 6210-01-026-9673	2
FU1	Fuse, NSN 5920-00-280-8342, Holder, NSN 5920-00-228-4432	1
R1, 4, 13, 16	Resistor, 1k, _ W, NSN 5905-00-110-7620	5
R3	Resistor, 4.7M, _ W, NSN 5905-00-126-6694	1
R5	Resistor, 100k, _ W, NSN 5905-00-104-8336	1
R6, 7	Resistor, 4.7k, _ W, NSN 5905-00-038-6136	2
R8	Potentiometer, 10k, NSN 5905-00-397-3032	1
R9	Potentiometer, 100k, Allied No. 753-0244	1
	Dial, NSN 5355-00-441-9011	1
R10, 11, 17	Resistor, 100 Ohms, 2 W, NSN 5905-00-138-7140	3
R12	Resistor, 10k, 2 W, NSN 5905-00-184-7703	1
R14	Resistor, 0.5 Ohms, 5 W, NSN 5905-00-153-4354	1
C1	Capacitor, 0.01 uF, NSN 5910-00-024-9699	1
C2, 4-8	Capacitor, 0.1 uF, NSN 5910-00-113-5499	6
C3	Capacitor, 100 pF, NSN 5910-01-233-2045	1
C9	Capacitor, 200 uF, 200 V, Sprague No. 36DX200F200BC2A	1
101	Cabinet, Control Box, NSN 5975-00-372-3656	1
102	Cabinet, Power Box, NSN 5975-00-901-6112	1
103	Cable Assembly, 18 AWG, NSN 6150-00-431-8027	1
Q1	Diode, Motorola No. MUR6040	1
D2	Diode, 1N4005, NSN 5961-00-356-3978	1
T1	Transformer, EG&G No. TR-1855	1
J1	Connector, Receptacle, NSN 5935-00-553-3304	1
J2	Connector, Receptacle, NSN 5935-00-665-7657	1
P1	Connector, Plug, NSN 5935-00-549-4955	1
P2	Connector, Plug, NSN 5935-00-622-2917	1
C10	Capacitor, 1000 pF, NSN 5910-00-024-9699	1
R2	Resistor, 470 Ohms, _ W, NSN 5905-00-120-9154	1
J3-5, 10-12	Jack, Banana, Black, NSN 5935-00-813-1682	6
J6-9	Jack, Banana, Red, NSN 5935-00-813-1681	4
I1, 2	Insulator, High Voltage, Daburn No. 10-76	2
K1	Relay, Magnecraft No. W104MIP-42	1

Figure A-2 Mars Spark Source Prototype Interconnection Diagram



Appendix B

Mars Spark Source Prototype Test Description

The MSSP test configuration for spark characterization is shown in figure 3 and the test hardware is shown in table B-1.

TABLE B-1.—TEST HARDWARE

Description	Manufacturer	Model
Control Box	NASA GRC	Prototype
Power Box	NASA GRC	Prototype
Power Supply	HP	E3612A
Test Chamber	NASA GRC	Prototype
Digital Oscilloscope (Spark Voltage and Current)	HP	54503
Digital Oscilloscope (Control Box Pulse Output)	Hitachi	VC-5460
HPIB Cable	HP	
Current Probe	Tektronix	A6303
Current Probe Amplifier	Tektronix	AM 503
High Voltage Probe	Tektronix	P6015A
Multimeter	HP	45 (34401A)
PC	Zenith	486

For spark characterization, the MSSP is set up in its normal operating configuration as shown in figure 2 and then the additional necessary test equipment is connected. An oscilloscope connected to the PULSE OUT of the Control Box is used to monitor the control signal. A dc voltmeter connected to the CAP V of the Power Box is used to monitor the actual energy storage capacitor voltage and to determine when the circuit is safe to handle. A nonintrusive precision current probe is used to monitor the spark current. A precision high voltage probe is used to monitor the spark voltage. The spark current signal and the spark voltage signal are taken to a dual channel digital storage oscilloscope. The digital output signal from the digital storage oscilloscope is taken to a personal computer that has been programmed to calculate the spark energy.

Appendix C

Mars Spark Source Prototype Test Results

A complete set of tables and plots of the test results are included here. Table 2 identifies the tests that were conducted.

The pulsewidth dial was calibrated and the results are indicated in table C-1.

TABLE C-1.—PULSEWIDTH

Dial setting	Pulsewidth (Microseconds)	
	0.01 MFD	100 pF
0.0	12.7	4.20
1.0	22.0	4.45
2.0	31.2	5.20
3.0	40.3	5.85
4.0	49.4	6.35
5.0	58.5	6.7
6.0	67.8	7.0
7.0	76.9	7.5
8.0	86.2	8.2
9.0	95.8	9.5
10.0	105.3	11.15

Each test point indicated in table II was tested three times to determine variation. The variation in spark energy for each of the three tests per test point was found to be very small, so only the mean energy is indicated in the tables and charts below. Several of the test points are not allowable due to constraints upon the safe operating area of the power electronics. These points are indicated by N/A in the tables. Several of the test points did not provide a spark because of insufficient energy to initiate a spark under the specified test conditions. These are indicated by N/S in the tables.

MEAN SPARK ENERGY (millijoules)
1 Atmosphere of Air
2mm Gap

t = 4us

VOLTAGE		NO. OF SPARKS			
IN (V)	OUT (kV)	1	2	5	10
8.26	1	N/S	N/S	N/S	N/S
16.53	2	N/S	N/S	N/S	N/S
41.32	5	N/S	N/S	1.5	2.3
82.64	10	N/S	N/S	1.7	2.8
100.00	12	N/S	N/S	1/7	2.8
120.00	14.4	N/S	N/S	1.8	2.8

t = 10us

VOLTAGE		NO. OF SPARKS			
IN (V)	OUT (kV)	1	2	5	10
8.26	1	N/S	N/S	N/S	N/S
16.53	2	N/S	N/S	N/S	N/S
41.32	5	1.0	1.9	5.2	10.7
82.64	10	1.4	2.5	6.7	12.6
100.00	12	1.4	2.6	6.7	12.0
120.00	14.4	1.6	3.0	6.9	13.6

t = 50us

VOLTAGE		NO. OF SPARKS			
IN (V)	OUT (kV)	1	2	5	10
8.26	1	N/S	N/S	N/S	N/S
16.53	2	N/S	N/S	N/S	N/S
41.32	5	2.7	5.5	12.7	26.4
82.64	10	3.9	6.8	13.4	32.4
100.00	12	N/A	N/A	N/A	N/A
120.00	14.4	N/A	N/A	N/A	N/A

t = 100us

VOLTAGE		NO. OF SPARKS			
IN (V)	OUT (kV)	1	2	5	10
8.26	1	N/S	N/S	N/S	N/S
16.53	2	N/S	N/S	N/S	N/S
41.32	5	4.6	8.9	24.0	45.8
82.64	10	N/A	N/A	N/A	N/A
100.00	12	N/A	N/A	N/A	N/A
120.00	14.4	N/A	N/A	N/A	N/A

MEAN SPARK ENERGY (millijoules)
1 Atmosphere of Air
5mm Gap

t = 4us

VOLTAGE		NO. OF SPARKS			
IN (V)	OUT (kV)	1	2	5	10
8.26	1	N/S	N/S	N/S	N/S
16.53	2	N/S	N/S	N/S	N/S
41.32	5	N/S	N/S	N/S	N/S
82.64	10	N/S	N/S	N/S	N/S
100.00	12	N/S	N/S	N/S	N/S
120.00	14.4	N/S	1.9	2.1	3.6

t = 10us

VOLTAGE		NO. OF SPARKS			
IN (V)	OUT (kV)	1	2	5	10
8.26	1	N/S	N/S	N/S	N/S
16.53	2	N/S	N/S	N/S	N/S
41.32	5	N/S	N/S	N/S	N/S
82.64	10	1.2	2.6	5.9	11.7
100.00	12	1.5	3.1	6.1	14.3
120.00	14.4	1.3	3.9	10.2	17.6

t = 50us

VOLTAGE		NO. OF SPARKS			
IN (V)	OUT (kV)	1	2	5	10
8.26	1	N/S	N/S	N/S	N/S
16.53	2	N/S	N/S	N/S	N/S
41.32	5	N/S	N/S	N/S	N/S
82.64	10	N/S	2.2	16.2	31.0
100.00	12	N/A	N/A	N/A	N/A
120.00	14.4	N/A	N/A	N/A	N/A

t = 100us

VOLTAGE		NO. OF SPARKS			
IN (V)	OUT (kV)	1	2	5	10
8.26	1	N/S	N/S	N/S	N/S
16.53	2	N/S	N/S	N/S	N/S
41.32	5	N/S	N/S	N/S	N/S
82.64	10	N/A	N/A	N/A	N/A
100.00	12	N/A	N/A	N/A	N/A
120.00	14.4	N/A	N/A	N/A	N/A

MEAN SPARK ENERGY (millijoules)
1 Atmosphere of Air
10mm Gap

t = 4us

VOLTAGE		NO. OF SPARKS			
IN (V)	OUT (kV)	1	2	5	10
8.26	1	N/S	N/S	N/S	N/S
16.53	2	N/S	N/S	N/S	N/S
41.32	5	N/S	N/S	N/S	N/S
82.64	10	N/S	N/S	N/S	N/S
100.00	12	N/S	N/S	N/S	N/S
120.00	14.4	N/S	N/S	N/S	N/S

t = 10us

VOLTAGE		NO. OF SPARKS			
IN (V)	OUT (kV)	1	2	5	10
8.26	1	N/S	N/S	N/S	N/S
16.53	2	N/S	N/S	N/S	N/S
41.32	5	N/S	N/S	N/S	N/S
82.64	10	N/S	N/S	N/S	N/S
100.00	12	N/S	N/S	N/S	N/S
120.00	14.4	N/S	N/S	N/S	N/S

t = 50us

VOLTAGE		NO. OF SPARKS			
IN (V)	OUT (kV)	1	2	5	10
8.26	1	N/S	N/S	N/S	N/S
16.53	2	N/S	N/S	N/S	N/S
41.32	5	N/S	N/S	N/S	N/S
82.64	10	N/S	N/S	N/S	N/S
100.00	12	N/A	N/A	N/A	N/A
120.00	14.4	N/A	N/A	N/A	N/A

t = 100us

VOLTAGE		NO. OF SPARKS			
IN (V)	OUT (kV)	1	2	5	10
8.26	1	N/S	N/S	N/S	N/S
16.53	2	N/S	N/S	N/S	N/S
41.32	5	N/S	N/S	N/S	N/S
82.64	10	N/A	N/A	N/A	N/A
100.00	12	N/A	N/A	N/A	N/A
120.00	14.4	N/A	N/A	N/A	N/A

MEAN SPARK ENERGY (millijoules)
10 Torr of Air
2mm Gap

t = 4us

VOLTAGE		NO. OF SPARKS			
IN (V)	OUT (kV)	1	2	5	10
8.26	1	N/S	N/S	N/S	N/S
16.53	2	N/S	N/S	N/S	N/S
41.32	5	0.2	0.3	1.5	2.1
82.64	10	1.0	1.1	3.5	6.7
100.00	12	1.3	1.5	4.5	7.9
120.00	14.4	1.7	3.2	4.9	8.1

t = 10us

VOLTAGE		NO. OF SPARKS			
IN (V)	OUT (kV)	1	2	5	10
8.26	1	N/S	N/S	N/S	N/S
16.53	2	0.3	0.6	1.0	1.7
41.32	5	1.6	2.4	5.6	10.8
82.64	10	2.9	5.9	12.0	21.9
100.00	12	3.2	6.3	11.7	21.9
120.00	14.4	3.6	6.8	12.2	19.0

t = 50us

VOLTAGE		NO. OF SPARKS			
IN (V)	OUT (kV)	1	2	5	10
8.26	1	N/S	N/S	N/S	N/S
16.53	2	N/S	N/S	N/S	N/S
41.32	5	5.8	8.7	15.1	26.3
82.64	10	8.6	12.2	22.3	35.3
100.00	12	N/A	N/A	N/A	N/A
120.00	14.4	N/A	N/A	N/A	N/A

t = 100us

VOLTAGE		NO. OF SPARKS			
IN (V)	OUT (kV)	1	2	5	10
8.26	1	N/S	N/S	N/S	N/S
16.53	2	4.4	5.6	9.2	12.8
41.32	5	11.1	15.5	24.3	38.8
82.64	10	N/A	N/A	N/A	N/A
100.00	12	N/A	N/A	N/A	N/A
120.00	14.4	N/A	N/A	N/A	N/A

MEAN SPARK ENERGY (millijoules)
10 Torr of Air
5mm Gap

t = 4us

VOLTAGE		NO. OF SPARKS			
IN (V)	OUT (kV)	1	2	5	10
8.26	1	N/S	N/S	N/S	N/S
16.53	2	N/S	N/S	N/S	N/S
41.32	5	N/S	0.6	1.7	3.2
82.64	10	1.2	2.5	4.9	8.3
100.00	12	1.3	2.6	4.8	8.5
120.00	14.4	1.6	3.3	4.9	10.2

t = 10us

VOLTAGE		NO. OF SPARKS			
IN (V)	OUT (kV)	1	2	5	10
8.26	1	N/S	N/S	N/S	N/S
16.53	2	N/S	N/S	N/S	N/S
41.32	5	1.1	3.0	6.5	10.9
82.64	10	2.8	6.8	13.3	21.6
100.00	12	3.8	8.0	14.0	23.0
120.00	14.4	4.8	9.0	14.5	23.6

t = 50us

VOLTAGE		NO. OF SPARKS			
IN (V)	OUT (kV)	1	2	5	10
8.26	1	N/S	N/S	N/S	N/S
16.53	2	N/S	N/S	N/S	N/S
41.32	5	7.8	10.6	18.1	28.8
82.64	10	10.3	14.8	26.5	40.8
100.00	12	N/A	N/A	N/A	N/A
120.00	14.4	N/A	N/A	N/A	N/A

t = 100us

VOLTAGE		NO. OF SPARKS			
IN (V)	OUT (kV)	1	2	5	10
8.26	1	N/S	N/S	N/S	N/S
16.53	2	N/S	N/S	N/S	N/S
41.32	5	12.0	15.8	25.7	42.2
82.64	10	N/A	N/A	N/A	N/A
100.00	12	N/A	N/A	N/A	N/A
120.00	14.4	N/A	N/A	N/A	N/A

MEAN SPARK ENERGY (millijoules)
10 Torr of Air
10mm Gap

t = 4us

VOLTAGE		NO. OF SPARKS			
IN (V)	OUT (kV)	1	2	5	10
8.26	1	N/S	N/S	N/S	N/S
16.53	2	N/S	N/S	N/S	N/S
41.32	5	N/S	N/S	N/S	N/S
82.64	10	1.1	1.7	3.8	8.6
100.00	12	1.5	1.7	4.9	11.0
120.00	14.4	1.5	2.6	6.0	11.0

t = 10us

VOLTAGE		NO. OF SPARKS			
IN (V)	OUT (kV)	1	2	5	10
8.26	1	N/S	N/S	N/S	N/S
16.53	2	N/S	N/S	N/S	N/S
41.32	5	N/S	3.2	7.0	12.8
82.64	10	2.6	7.8	15.4	26.1
100.00	12	3.4	9.1	16.8	25.8
120.00	14.4	7.1	10.7	17.4	28.5

t = 50us

VOLTAGE		NO. OF SPARKS			
IN (V)	OUT (kV)	1	2	5	10
8.26	1	N/S	N/S	N/S	N/S
16.53	2	N/S	N/S	N/S	N/S
41.32	5	7.3	9.1	19.2	29.7
82.64	10	12.8	17.1	29.5	28.2
100.00	12	N/A	N/A	N/A	N/A
120.00	14.4	N/A	N/A	N/A	N/A

t = 100us

VOLTAGE		NO. OF SPARKS			
IN (V)	OUT (kV)	1	2	5	10
8.26	1	N/S	N/S	N/S	N/S
16.53	2	N/S	N/S	N/S	N/S
41.32	5	13.7	19.9	33.2	44.6
82.64	10	N/A	N/A	N/A	N/A
100.00	12	N/A	N/A	N/A	N/A
120.00	14.4	N/A	N/A	N/A	N/A

MEAN SPARK ENERGY (millijoules)
10 Torr of Carbon Dioxide
2mm Gap

t = 4us

VOLTAGE		NO. OF SPARKS			
IN (V)	OUT (kV)	1	2	5	10
8.26	1	N/S	N/S	N/S	N/S
16.53	2	N/S	N/S	N/S	N/S
41.32	5	N/S	N/S	N/S	N/S
82.64	10	1.1	2.0	4.4	7.1
100.00	12	1.5	1.9	4.6	9.5
120.00	14.4	1.8	2.2	5.2	10.0

t = 10us

VOLTAGE		NO. OF SPARKS			
IN (V)	OUT (kV)	1	2	5	10
8.26	1	N/S	N/S	N/S	N/S
16.53	2	N/S	N/S	N/S	N/S
41.32	5	2.0	3.2	6.8	11.7
82.64	10	3.0	7.7	14.4	27.2
100.00	12	3.1	9.4	17.7	27.9
120.00	14.4	5.1	11.2	17.9	27.4

t = 50us

VOLTAGE		NO. OF SPARKS			
IN (V)	OUT (kV)	1	2	5	10
8.26	1	N/S	N/S	N/S	N/S
16.53	2	N/S	N/S	N/S	N/S
41.32	5	8.0	12.1	18.5	34.4
82.64	10	11.6	16.9	32.2	46.3
100.00	12	N/A	N/A	N/A	N/A
120.00	14.4	N/A	N/A	N/A	N/A

t = 100us

VOLTAGE		NO. OF SPARKS			
IN (V)	OUT (kV)	1	2	5	10
8.26	1	N/S	N/S	N/S	N/S
16.53	2	N/S	N/S	N/S	N/S
41.32	5	11.0	20.1	34.0	47.0
82.64	10	N/A	N/A	N/A	N/A
100.00	12	N/A	N/A	N/A	N/A
120.00	14.4	N/A	N/A	N/A	N/A

MEAN SPARK ENERGY (millijoules)
10 Torr of Carbon Dioxide
5mm Gap

t = 4us

VOLTAGE		NO. OF SPARKS			
IN (V)	OUT (kV)	1	2	5	10
8.26	1	N/S	N/S	N/S	N/S
16.53	2	N/S	N/S	N/S	N/S
41.32	5	N/S	N/S	N/S	N/S
82.64	10	1.3	2.4	4.5	8.3
100.00	12	1.5	2.0	5.3	10.2
120.00	14.4	2.0	4.0	7.9	12.0

t = 10us

VOLTAGE		NO. OF SPARKS			
IN (V)	OUT (kV)	1	2	5	10
8.26	1	N/S	N/S	N/S	N/S
16.53	2	N/S	N/S	N/S	N/S
41.32	5	N/S	3.1	7.7	13.5
82.64	10	3.8	8.0	15.3	25.0
100.00	12	4.0	8.7	16.0	24.7
120.00	14.4	4.5	8.9	15.3	25.0

t = 50us

VOLTAGE		NO. OF SPARKS			
IN (V)	OUT (kV)	1	2	5	10
8.26	1	N/S	N/S	N/S	N/S
16.53	2	N/S	N/S	N/S	N/S
41.32	5	6.2	11.1	21.1	32.2
82.64	10	9.5	15.3	28.2	36.8
100.00	12	N/A	N/A	N/A	N/A
120.00	14.4	N/A	N/A	N/A	N/A

t = 100us

VOLTAGE		NO. OF SPARKS			
IN (V)	OUT (kV)	1	2	5	10
8.26	1	N/S	N/S	N/S	N/S
16.53	2	N/S	N/S	N/S	N/S
41.32	5	9.7	13.7	37.5	44.3
82.64	10	N/A	N/A	N/A	N/A
100.00	12	N/A	N/A	N/A	N/A
120.00	14.4	N/A	N/A	N/A	N/A

MEAN SPARK ENERGY (millijoules)
10 Torr of Carbon Dioxide
10mm Gap

t = 4us

VOLTAGE		NO. OF SPARKS			
IN (V)	OUT (kV)	1	2	5	10
8.26	1	N/S	N/S	N/S	N/S
16.53	2	N/S	N/S	N/S	N/S
41.32	5	N/S	N/S	N/S	N/S
82.64	10	1.3	2.0	5.0	10.6
100.00	12	1.6	2.0	5.1	11.3
120.00	14.4	2.1	2.5	6.2	11.2

t = 10us

VOLTAGE		NO. OF SPARKS			
IN (V)	OUT (kV)	1	2	5	10
8.26	1	N/S	N/S	N/S	N/S
16.53	2	N/S	N/S	N/S	N/S
41.32	5	2.2	3.9	8.1	14.9
82.64	10	5.2	9.5	16.3	26.3
100.00	12	7.4	9.3	16.9	26.2
120.00	14.4	8.2	10.1	16.0	26.2

t = 50us

VOLTAGE		NO. OF SPARKS			
IN (V)	OUT (kV)	1	2	5	10
8.26	1	N/S	N/S	N/S	N/S
16.53	2	N/S	N/S	N/S	N/S
41.32	5	N/S	N/S	N/S	37.9
82.64	10	10.3	17.6	28.4	38.6
100.00	12	N/A	N/A	N/A	N/A
120.00	14.4	N/A	N/A	N/A	N/A

t = 100us

VOLTAGE		NO. OF SPARKS			
IN (V)	OUT (kV)	1	2	5	10
8.26	1	N/S	N/S	N/S	N/S
16.53	2	N/S	N/S	N/S	N/S
41.32	5	9.7	12.7	28.7	44.7
82.64	10	N/A	N/A	N/A	N/A
100.00	12	N/A	N/A	N/A	N/A
120.00	14.4	N/A	N/A	N/A	N/A

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13. ABSTRACT ***(Maximum 200 words)***

The Mars Spark Source Prototype (MSSP) hardware has been developed as part of a proof of concept system for the detection of trace metals such as lead, cadmium, and arsenic in Martian dusts and soils. A spark discharge produces plasma from a soil sample and detectors measure the optical emission from metals in the plasma that will allow their identification and quantification. Trace metal measurements are vital for the assessment of the potential toxicity of the Martian environment for human exploration. The current method of X-ray fluorescence can yield concentrations only of major species. Other instruments are incompatible with the volume, weight, and power constraints for a Mars mission. The instrument will be developed primarily for use in the Martian environment, but would be adaptable for terrestrial use in environmental monitoring. This paper describes the Mars Spark Source Prototype hardware, the results of the characterization tests, and future plans for hardware development.

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